California Environmental Protection Agency

Air Resources Board

DRAFT FOR PUBLIC REVIEW

Report to the California Legislature

INDOOR AIR POLLUTION IN CALIFORNIA

A report submitted by:

California Air Resources Board

Pursuant to Health and Safety Code § 39930
(Assembly Bill 1173, Keeley, 2002)

June 2004

Arnold Schwarzenegger, Governor

ACKNOWLEDGEMENTS

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Instructions for Reviewers

Thank you for your interest in this report. This draft report has been prepared in response to Assembly Bill 1173, Keeley (2002), which requires the Air Resources Board to prepare a report on indoor air quality and its impacts in California. We welcome comments on this report. Written comments should be received no later than August 20, 2004; earlier receipt will be appreciated. Please direct all comments to either the following postal or electronic mail address:

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A public workshop will be held to discuss this report. At the workshop, ARB staff will briefly summarize the report and respond to public questions and comments. Those unable to attend the workshop can comment or provide information by mail. Additionally, the workshop will be webcast. The workshop is scheduled as follows:

Date:	Tuesday, July 27, 2004
Time:	1:00 to 4:00 p.m.
Location:	Training Room 1, East and West Cal/EPA Building 1001 I Street Sacramento, California 95814

This report and additional information on AB1173, including our anticipated schedule for completion of the report, are available on the ARB website at: www.arb.ca.gov/research/indoor/ab1173/ab1173.htm.

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ACRONYMS

ACRONYM	DEFINITION
AAQS	Ambient Air Quality Standards
AB	Assembly Bill
ACM	Asbestos containing material
AHERA	Asbestos Hazard Emergency Response Act
ANSI	American National Standards Institute
ARB	California Air Resources Board
ASHRAE	American Society of Heating, Refrigerating, and Air-conditioning Engineers
CADR	Clean air delivery rate
Cal/EPA	California Environmental Protection Agency
Cal/OSHA	California Department of Industrial Relations, Division of Occupational Safety and Health
CCR	California Code of Regulations
CDC	U.S. Center for Disease Control
CDE	California Department of Education
CDFA	California Department of Food and Agriculture
CEC	California Energy Commission
CHPS	Collaborative for High Performance Schools
CIWMB	California Integrated Waste Management Board
CPA	Composite Panel Association
CRI	Carpet and Rug Institute
DGS	California Department of General Services
DHS	California Department of Health Services
DOE	U.S. Department of Energy
DOF	California Department of Finance
EPA	U.S. Environmental Protection Agency
HEPA	High efficiency particulate arrestance
HSC	California Health and Safety Code
HVAC	Heating, ventilating, and air conditioning
IAQ	Indoor air quality
IDEC	Indirect-direct evaporative cooling
IEQ	Indoor environmental quality
IESNA	Illumination Engineering Society of North America
IREL	Interim (Indoor) reference exposure level
LAUSD	Los Angeles Unified School District
LEED™	Leadership in Energy and Environmental Design
MCL	Maximum contaminant level
MDI	Methyl diisocyanate
NO_2	Nitrogen dioxide
NO_x	Nitrogenous compounds
NOEL	No observable effect level
O&M	Operation and maintenance
OEHHA	California Office of Environmental Health Hazard Assessment
OP	Organophosphate pesticide
OSHA	U.S. Occupational Safety and Health Administration
PACM	Presumed asbestos containing material

PAH	Polycyclic aromatic hydrocarbon
PBDE	Polybrominated diphenyl ethers
PBO	Piperonyl butoxide
PCB	Polychlorinated biphenyls
PCS	Portable Classrooms Study
PEL	Permissible exposure limit
PM	Particulate matter
REL	Reference exposure limit
RH	Relative humidity
RSP	Respirable suspended particulate
SB	Senate Bill
SBS	Sick building syndrome
SCSA	State and Consumer Services Agency
TVOC	Total volatile organic compounds
U.S. EPA	United States Environmental Protection Agency
USD	Unified School District
VOC	Volatile organic compound, volatile organic chemical
WHO	World Health Organization

ABBREVIATIONS AND SYMBOLS

TERM	DEFINITION
^oC	degrees Celsius
cfm	cubic feet per minute
CFU	colony forming unit
cm^2	square centimeter
CO	carbon monoxide
CO_2	carbon dioxide
dBA	decibel (referenced to 1 ampere)
^oF	degrees Fahrenheit
kg	kilogram (one thousand grams)
l/min.	liters per minute (flow rate)
m^2	square meter
m^3	cubic meter
µg	microgram (one-millionth of a gram)
µg/g	micrograms per gram (concentration)
$\mu g/cm^2$	micrograms per cubic meter (surface area)
$\mu g/m^3$	micrograms per cubic meter (concentration)
mg	milligrams (one-thousandth of a gram)
mg/kg	milligrams per kilogram (concentration)
ml	milliliter (one-millionth of a liter)
ng	nanogram (one-billionth of a gram)
ng/g	nanograms per gram (concentration)
No.	number
%	percent
pCi/L	picoCurie per liter
PM2.5	particulate matter with aerodynamic diameter less than 2.5 microns
PM10	particulate matter with aerodynamic diameter less than 10 microns
ppb	parts per billion (such as one grain of sand in a billion grains of sand)
ppm	parts per million (such as one grain of sand in a million grains of sand)
§	section
T	temperature

EXECUTIVE SUMMARY

I. INTRODUCTION

The California Air Resources Board (ARB) staff is preparing this report to the Legislature on indoor air quality in response to requirements of Assembly Bill 1173 (Keeley, 2002; California Health and Safety Code [HSC] Section [§] 39930). This report summarizes the best scientific information available on indoor air pollution, including: information on common indoor pollutants and their sources; the potential health impacts of indoor pollutants, and associated costs; existing regulations and practices; options for mitigation in schools, homes, and non-industrial workplaces; and other information specified in the legislation. Stakeholder input is being obtained from relevant state agencies, industries, interest groups, and the public. Before it is submitted to the Legislature, the report will undergo scientific peer review by a panel of University of California scientists, and will be considered by the California Air Resources Board.

Indoor Air Pollution Poses Substantial Health Risks

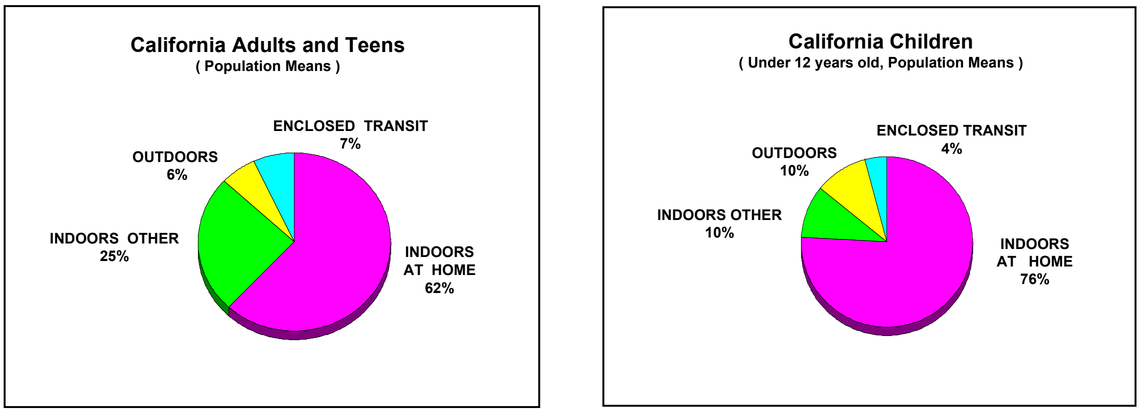
Available scientific information indicates that indoor air pollution poses substantial health risks in many indoor environments. In comparative risk projects that ranked environmental health problems in order of the risk they pose to health and the environment, both the California and U.S. Environmental Protection Agencies ranked indoor pollutants and sources in the high-risk categories. Outdoor pollution emissions from motor vehicles and stationary (industrial) sources also were ranked high. Indoor pollution ranked high relative to other environmental problems because there are numerous sources of pollutants indoors, indoor air concentrations of some pollutants often occur at levels that create significant health risks, and people spend most of their time indoors. These factors lead to high exposure indoors to some pollutants, and result in significant risk. While regulation of outdoor sources such as motor vehicles and industrial facilities is very extensive and has notably reduced pollutant levels in California, indoor pollution sources have not been addressed in a comprehensive manner. If such an effort were established, significant gains could be achieved in public health protection from reductions in indoor source emissions and from other measures that might be taken to reduce indoor concentrations and exposures.

Why Indoor Sources Have Such a Significant Impact

The total quantity of air pollutants emitted indoors is less than that emitted by outdoor sources. However, once emitted, indoor air pollutants are much less diluted, due to the partial trapping effect of the building shell. Additionally, indoor emissions occur in closer proximity to people: Californians, like others from industrialized nations, spend most of their time indoors. As shown in Figure ES-1, California adults spend an average of 87% of their time indoors, and children under 12 years of age spend about 86% of their time indoors. Most of the time spent indoors is spent in the home, although working adults spend about 25% of their time at other indoor locations such as office buildings, stores, and restaurants, primarily for work, and children spend about 21% of their time in school on a school day. Senior individuals spend a great deal of time in their homes. Because of these time budgets, the trapping effect of buildings, and people's proximity to indoor sources of emissions, there is a much higher likelihood that people will be exposed to indoor pollutants. One investigator has calculated that pollutants emitted indoors have a 1000-fold greater chance of being inhaled than do those same pollutants emitted outdoors (Smith, 1988).

Homes and schools are thus critical exposure microenvironments, especially for children and seniors. These groups are most sensitive to the adverse effects of some pollutants, and spend most of their time indoors.

Figure ES-1:
Where Californians Spend Time



Children Are Especially Vulnerable to Poor Indoor Air Quality

Children may be especially vulnerable to poor indoor air quality due to several factors. Children's physiology and developing bodies make them more susceptible to chemicals that affect development and lung function. Their immune systems are not fully developed, and their growing organs are more easily harmed. Additionally, infants and children inhale more air relative to their size than do adults at a given level of activity, so that they inhale a larger dose of pollutants than do adults in the same environment. Children also tend to be more active than adults. These factors, combined with elevated indoor concentrations of pollutants, can lead to higher exposure and risk for children.

II. HEALTH EFFECTS OF INDOOR POLLUTANTS

Indoor air pollution can cause a variety of impacts on human health, from irritant effects to respiratory disease, cancer, and premature death. Indoor levels of many pollutants are often elevated to levels that can result in adverse health impacts. The major indoor pollutants that have the greatest known impact on Californians' health are listed in Table ES-1, along with their sources and associated health impacts. The health impacts of greatest significance include asthma, cancer, premature death, respiratory disease and symptoms, and irritant effects.

Asthma

Asthma is a chronic inflammatory lung disease that results in constriction of the airways. It has increased dramatically both in California and throughout the country over the past few decades.

Table ES-1. Sources and Potential Health Effects of Major Indoor Air Pollutants

POLLUTANT	MAJOR INDOOR SOURCES	POTENTIAL HEALTH EFFECTS
Organic Chemicals (benzene, styrene, para-dichlorobenzene, chloroform, perchloroethylene, methylene chloride, phthalates, etc.)	Solvents; glues; cleaning agents; pesticides; building materials; paints; treated water; moth repellents; dry-cleaned clothing; air fresheners;	Cancer; eye, nose, throat irritation; possible worsening of asthma; headaches; at high levels; loss of coordination; damage to liver, kidney and brain
Formaldehyde, Other Aldehydes	Composite wood products such as plywood and particleboard; furnishings; wallpaper; durable press fabrics; paints	Cancer; eye, nose, and throat irritation; headache; allergic reactions; worsening of asthma
Particulate Matter	Cigarettes, wood stoves, fireplaces, cooking, candles, aerosol sprays, house dust	Increased mortality and hospital admissions; lung cancer; eye, nose, throat irritation; increased susceptibility to sinus and respiratory infections; bronchitis; worsening of asthma
Environmental Tobacco Smoke (ETS)	Cigarettes, cigars, and pipes	Respiratory irritation, bronchitis and pneumonia in children; lung cancer; heart disease; worsening of asthma
Carbon Monoxide	Unvented or malfunctioning gas and propane appliances, wood stoves, fireplaces, tobacco smoke	Headache; nausea; angina; impaired vision and mental functioning; fatal at high concentrations
Nitrogen Dioxide	Unvented or malfunctioning gas appliances, other combustion appliances	Worsening of asthma; eye, nose, and throat irritation; increased respiratory disease in children
Radon	Soil under buildings, ground-water, construction materials	Lung cancer (especially in smokers)
Biological Agents (bacteria, fungi, house dust mites, animal dander; cockroaches)	House dust; pets; bedding; poorly maintained air-conditioners, humidifiers and dehumidifiers; wet or moist structures; furnishings	Allergic reactions; asthma; eye, nose, and throat irritation; humidifier fever, influenza, and other infectious diseases
Polycyclic Aromatic Hydrocarbons (PAH)	Cigarette smoke, cooking, burning wood	Cancer; gene mutation
Endocrine Disrupters (phthalates; DDT, chlordane, heptachlor, *o*-phenylphenol; PBDEs)	Plastics; pesticides; flame retardants	Mimic or block natural effects of hormones (estrogen and others); developmental abnormalities

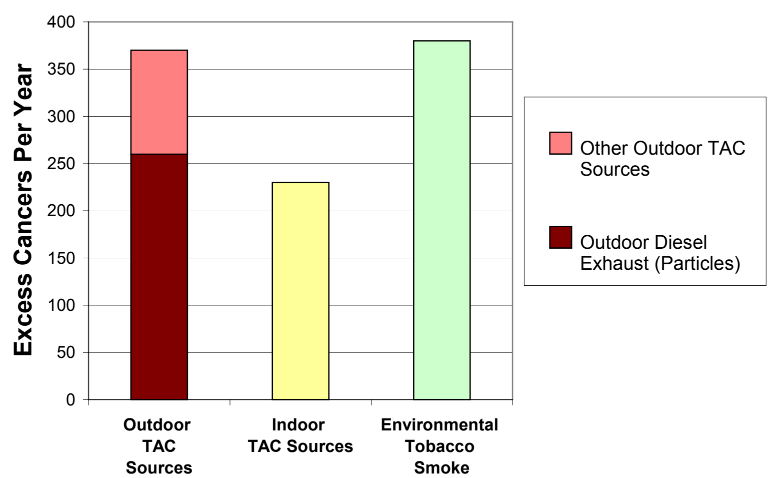
Children have been especially affected; in California, asthma prevalence is greatest among 12 to 17 year olds.

Indoor air pollutants exacerbate asthma symptoms, resulting in breathing difficulties. A recent Institute of Medicine (National Academy) report, *Clearing the Air: Asthma and Indoor Exposures* (IOM, 2000), identified new associations between indoor air pollutants and asthma, in addition to the traditional indoor asthma triggers such as cat and dog dander, house dust mites, and environmental tobacco smoke (ETS). The scientists found sufficient evidence of an association between exacerbation of asthma and exposure to nitrogen dioxide (NO_2), other nitrogen species (NO_X), and mold, and limited or suggestive evidence of an association of formaldehyde and fragrances with asthma. A more recent review of indoor pollution studies further identified several links between asthma symptoms and volatile organic chemicals (VOCs), especially formaldehyde (Delfino, 2002). Studies of workplace asthma have further demonstrated an association between asthma symptoms and VOCs, primarily from cleaning products (Rosenman *et al.*, 2003).

Cancer

A substantial number of common indoor pollutants have been classified as carcinogens. Examples include formaldehyde, benzo(a)pyrene and other polycyclic aromatic hydrocarbons (PAHs), tobacco smoke, benzene, chlorinated solvents such as tetrachloroethylene, and radon gas. Several studies have measured indoor concentrations of carcinogenic chemicals in California homes. Results have shown that carcinogens, especially formaldehyde, are routinely found in most homes, often at higher concentrations than concurrent outdoor levels, due to the presence of indoor sources. These exposures result in a significant increase in cancer risk attributable to indoor pollutants, primarily those emitted from building materials and consumer products. ARB staff estimate that about 230 excess cancer cases occur annually in California due to exposures from the limited number of indoor toxic air contaminants that can be quantified from residential and consumer sources. As shown in Figure ES-2, this estimate is similar in magnitude to the estimated cancer burden from outdoor diesel exhaust (particles), which is responsible for much of the excess cancer burden associated with breathing ambient air in California. This indoor cancer estimate also equals about two-thirds of the total burden from excess cancer resulting from outdoor air pollutant emissions.

Figure ES-2:
Estimated Potential Cancer Burden from Air Toxics in California by Source



Exposure to environmental tobacco smoke (ETS) makes a significant contribution to the cancer burden from air pollution as well. Current exposure and risk estimates for ETS are not available; therefore estimates from the mid-1990s are used here. Those ETS risk levels are similar to the total outdoor burden; however, because workplace exposure has decreased to nearly zero since the mid-1990s, and the prevalence of smoking has decreased substantially as well, the current cancer burden from ETS is expected to be substantially lower than shown in this graphic. Nonetheless, the contribution of ETS will remain significant, because some individuals including some children, are still exposed to substantial levels of ETS.

Irritant Effects

Many indoor pollutants cause eye, nose, throat, and respiratory tract irritation. Aldehydes and terpenes, as well as some other VOCs and oxidants, are known mucous membrane irritants. Formaldehyde is the most commonly identified irritant. Acute effects of irritant chemicals can include headache, difficulty breathing, and nausea. Chronic exposure is associated with respiratory symptoms and eye, nose, and throat irritation. Terpenes such as pinene and limonene are potentially reactive chemicals that are frequently used in cleaning products for their favorable odor characteristics and solvent properties. These and other irritant chemicals are commonly found indoors.

Irritant chemicals and other factors are suspected of causing or contributing to episodes of Sick Building Syndrome (SBS), in which a large number of building occupants experience irritant and neurological effects while they are in a building. The specific causes of SBS have not yet been firmly identified; however, SBS episodes can affect a high number of workers, have been well documented, and have resulted in high costs to some businesses due to reduced productivity and, in some cases, legal settlements. The most common symptoms include eye irritation, congested nose, headache, fatigue, difficulty concentrating, and skin rash.

Premature Death and Increased Disease

Several pollutants for which ambient air quality standards have been established occur at elevated levels indoors due to emissions from indoor sources. In other cases, indoor sources increase the high levels of exposure that occur when high levels of polluted ambient air enters the indoor space. Ambient particulate matter (PM) has been associated with premature mortality and serious respiratory and cardiovascular effects in numerous studies. Carbon monoxide (CO) can cause death with high exposures of relatively short duration, and lower levels can cause flu-like symptoms and other health effects. Nitrogen dioxide (NO_2) can harm the lungs and other mucous membranes, cause respiratory disease, and exacerbate asthma. Ozone can have similar effects at elevated levels; however, indoor levels are typically lower than outdoor levels. Indoor sources of these pollutants sometimes cause indoor concentrations that exceed health-based ambient air quality standards established for outdoor air.

Particulate matter

Particulate matter (PM) is a complex mixture of very small particles and other non-gaseous materials suspended in the air. Indoor particle sources include combustion devices such as woodstoves and fireplaces, and activities such as smoking, cooking, candle burning, and vacuuming, all of which can produce PM with harmful components similar to those found in outdoor air. Indoor particles also include fibrous materials, pollen, mold spores and fragments, and tracked-in soil particles. Pollens and mold can trigger allergies and asthma. Tracked-in particles and some particles from combustion sources become trapped in carpets and have been shown to include a mix of toxic components such as polycyclic aromatic hydrocarbons (PAHs) and lead.

A large number of major epidemiologic studies have consistently shown a strong association between outdoor (ambient) PM exposure and increased mortality from cardiovascular and respiratory disease. They also have shown increased morbidity effects with increased PM levels, including increased hospitalizations and emergency room visits due to respiratory problems such as asthma, chronic obstructive pulmonary disease (COPD), chronic bronchitis, and pneumonia; increased respiratory symptoms such as cough and wheeze; decreased lung function and reduced lung function growth in children; and increased cardiovascular disease such as congestive heart failure, stroke, and ischemic heart disease.

The studies documenting these effects measured outdoor particles, which are composed of a mix of particles from combustion sources, soil, and particles formed through chemical reactions in the atmosphere. Because a substantial portion of PM from indoor sources is similar to outdoor PM components, indoor PM emissions are likely to be significant contributors to the adverse impacts seen in the epidemiology studies, and they may also contribute to those effects beyond the levels quantified in the epidemiology studies.

ARB has estimated that reducing outdoor PM concentrations to the level of the current California ambient air quality standard for PM would result in significant reductions in adverse health effects, including approximately 6,500 deaths and 17,000 serious, non-fatal illnesses each year in California (ARB/OEHHA 2002). Although current studies have not directly addressed the potential impacts of indoor PM on health, if consistent with outdoor PM, the impacts of PM of indoor origin are likely to have very large impacts on public health, potentially resulting in thousands of additional cases of serious illness and disease each year.

Carbon monoxide

Carbon monoxide (CO) is a colorless, odorless gas. It is a product of incomplete combustion, emitted from sources such as vehicle exhaust, gas and propane stoves and furnaces, woodstoves, kerosene heaters, and cigarettes. CO can cause unconsciousness and even death at very high levels, or flu-like symptoms (headache, nausea, lethargy) and inability to concentrate at lower levels over periods of time.

Very high levels of CO occur relatively infrequently indoors. However, exposure to very high CO levels can be fatal. A California study of death certificates showed that about 30 – 40 deaths occur in California each year, on average, due to unintentional CO poisoning (Girman *et al.*, 1998; Liu *et al.*, 1993a, 2000). About two-thirds of those deaths are attributable to indoor sources. The indoor sources most implicated in past CO poisonings were combustion appliances, such as malfunctioning or poorly tuned gas or propane furnaces and stoves, and the improper use of charcoal grills and hibachis indoors (contrary to warnings). Motor vehicles, such as those unwisely left running in a garage, also have taken a substantial toll. The relevant literature also indicates that other CO health effects occur: hundreds of emergency room visits and thousands of misdiagnosed flu-like illnesses due to non-fatal CO poisoning are estimated to occur each year.

Nitrogen dioxide

Nitrogen dioxide (NO_2) is another colorless, tasteless gas emitted from combustion sources. Indoor sources of NO_2 include gas and propane appliances, wood burning stoves, kerosene heaters, charcoal grills, and motor vehicles in garages. Indoor levels can be especially elevated from the use of older wall furnaces, when their exhaust is not vented to the outdoors, and from gas stoves, because people often do not use the exhaust hoods above them, or the exhaust is not vented to the outdoors. Adverse health effects attributable to NO_2 include exacerbation of asthma in children, respiratory symptoms and infection, and lung damage.

Ozone

Ozone is a respiratory irritant and a main component of smog. Outdoor ozone is the primary source of indoor concentrations of ozone in the majority of indoor environments, but levels are typically much lower indoors. Breathing elevated concentrations of ozone can be harmful to health, especially for active people, including children. It can exacerbate asthma in some people, particularly those with concurrent allergen exposure. Ozone also is directly emitted indoors from some types of office equipment, such as poorly maintained laser printers, and some types of so-called “air cleaners”. Indoor areas with these sources can experience high levels of ozone, even when outdoor levels are low. Whether inhaled indoors or outdoors, ozone can cause respiratory tract irritation, which is manifested as coughing, wheezing, and pain on deep breathing, and can exacerbate asthma. Ozone masks the odor of other indoor pollutants by deadening the sense of smell. It also reacts with certain indoor pollutants to produce toxic by-products, such as formaldehyde.

Toxic Air Contaminants

Other pollutants designated as toxic air contaminants, based largely on their potential to cause cancer, also can occur at elevated levels indoors due to emissions from indoor sources.

- **Volatile Organic Compounds (VOCs)** – As mentioned above, VOCs such as formaldehyde and chlorinated solvents are common in indoor air, and can exacerbate asthma and cause cancer and irritant effects. Some of these chemicals also have reproductive or developmental effects, and some can affect the nervous system at very high levels encountered infrequently in certain non-industrial workplaces. Indoor levels of formaldehyde, a pungent smelling gas, nearly always exceed health-based guideline levels. Formaldehyde is emitted from numerous indoor sources including building materials (especially pressed wood products), carpets, composite wood furnishings, personal care products, cosmetics; permanent pressed clothing, and combustion sources.

- **Environmental Tobacco Smoke (ETS)** – ETS causes cancer, heart disease, asthma episodes, middle ear infections in children, and other adverse effects. Despite decreases in the percent of smokers in the population and the statewide prohibition of smoking in workplaces, some individuals, especially children, are still exposed to elevated levels of ETS in the homes and vehicles of smokers**.**

- **Polycyclic Aromatic Hydrocarbons (PAHs)** – PAHs, emitted from combustion sources such as cigarettes, woodstoves and fireplaces, include a number of known or suspected carcinogens. They have been found to adsorb onto particles in the air and deposit onto carpets, from which they can be resuspended during vacuuming or other activity.

- **Radon and asbestos** are other known lung carcinogens found indoors in some California environments. Radon levels in California are substantially lower than in most other states and typically lower than mitigation guideline levels. Indoor asbestos is elevated only infrequently, typically during remodeling of older buildings.

- **Pesticides and metals** – Pesticides are widely used and can cause adverse developmental and neurological effects at elevated exposure levels. Some are very persistent in the environment, lasting 20 or 30 years or more. Carpet dust from homes and schools have been shown to contain numerous residues of pesticides, lead, mercury and other long-lasting contaminants. This is of special concern for very young children, who spend time on the floor and put their hands in their mouths, because ingestion is often the primary route of exposure.

Biological Contaminants

Biological contaminants include substances of plant, animal, or microbial origin. They include bacteria, mold, pollen, house dust mites, and other substances, and are abundant in both indoor and outdoor environments. Excessive exposure to these contaminants is frequently associated with hypersensitivity reactions such as asthma attacks or allergy symptoms in sensitive individuals, and sinus or respiratory infection. Some mold and bacteria also can produce toxins that may cause reactions such as inflammation, vomiting, diarrhea, and immuno-suppression.

Many communicable diseases are primarily transmitted from person to person in indoor air. The inhalation of viruses is associated with influenza, measles, and chicken pox. Tuberculosis is a notorious infectious disease that is transmitted in closely occupied spaces. Other contaminants emanate from the building itself, rather than the people inside the building. Building-related illness (BRI) refers to a specific illness for which the specific cause can be identified within the building, such as bacteria in ventilation systems causing Legionnaires' disease, or humidifier fever. The usual causes of BRI include viruses, bacteria, and fungi. BRI impacts can be substantial, and are of increasing interest as the role of buildings in promoting diseases of biological contaminants becomes better understood.

III. INDOOR CONCENTRATIONS AND EXPOSURES

Indoor concentrations of many pollutants sometimes exceed health-based guideline levels or standards. Some pollutants, like formaldehyde, nearly always exceed recommended levels. Studies conducted by the ARB, the U.S. EPA, and others have shown that indoor levels of volatile organic chemicals (VOCs) and some other pollutants are typically elevated.

Additionally, people's "personal exposures" to pollutants, especially VOCs, are often greater than both indoor and outdoor pollutant levels. Personal exposures are measured by monitoring devices worn by the person throughout the day. Personal exposures to some pollutants are elevated because people spend time very near sources of pollutants, such as when using a gas stove, cleaning solutions, or personal care products. Pollutants become more diluted in the air as distance from the source increases. In studies, people and the monitors they wear are closer to sources throughout the day than are the indoor and outdoor monitors used for general air monitoring. Thus, for many pollutants, personal monitors provide the most accurate measure of people's actual exposures to air pollutants. Additionally, for VOCs and many other pollutants, personal exposure levels are most closely correlated with indoor concentrations.

Indoor – Outdoor Relationships

There is continuous air exchange between indoor environments and the outdoors. Outdoor emissions readily infiltrate into indoor environments, and indoor emissions seep outdoors and can contribute to outdoor air pollution. For example, ozone formed outdoors and fine particles and other emissions from nearby motor vehicles typically penetrate indoor environments to varying degrees, depending on the rate of air exchange, degree of filtration, and other factors. For residential buildings, the main entry routes of outdoor air are open windows and doors, gaps in the building shell, and devices such as swamp coolers that move outdoor air indoors. For large public and commercial buildings, the main entry route is through the mechanical heating, ventilating, and air conditioning (HVAC) systems, which actively move outdoor air indoors and typically filter some of the particles from the air. Any pollutants in the air just outside the building may thus be brought into the indoor space. Indoor pollutant levels can be much higher than those outdoors when indoor sources are present and the air exchange rate is low.

Similarly, indoor pollutants can flow through windows and penetrate small gaps in the building shell to contribute to the local outdoor burden of pollution. Emissions from certain sources used indoors, such as paints, consumer products, and gas and woodburning appliances contribute to local outdoor pollution levels, either through direct emissions or, in the case of reactive volatile organic chemicals, through chemical reactions.

Environmental Justice Considerations

ARB adopted an environmental justice policy in 2001. This policy requires the fair treatment of all people regardless of gender, ethnicity, and socioeconomic status. The limited research available indicates that some segments of the population may be disproportionately exposed to indoor pollutants. In California, African Americans, American Indians, and Alaska natives experience a higher prevalence of lifetime asthma (Meng *et al.*, 2003). However, in general, the prevalence of asthma appears to be more strongly correlated with lower socioeconomic status than with race and ethnicity (IOM, 2000). Dust mites, cockroaches, and mold are important triggers for asthmatics that are more likely to be present in urban settings where lower income individuals most often live. Additionally, research indicates blood lead levels are higher for poor and minority children in central cities. Formaldehyde levels have been highest in mobile homes, which are more often occupied by lower income families.

The ARB has taken steps to address some of these issues. Special air monitoring studies have been conducted at schools in some communities, and a large asthma study is underway. Fact sheets for public outreach have been published in English and Spanish. Efforts are underway to limit formaldehyde emissions from composite wood products through an Air Toxics Control Measure.

IV. COSTS OF INDOOR POLLUTION

Indoor air pollution takes a significant toll on Californians' lives and has significant economic costs. Exposure to indoor pollutants results in premature death and increased disease, increased expenditures for health care, decreased worker productivity, and decreased learning by school children. Table ES-2 shows estimates of the costs of indoor air pollution in California that are currently quantifiable. It includes the valuation of health (cost of premature death), an estimate of the increased expenditures for health care, and an estimate of some of the costs associated with reduced worker productivity. Because of the limited amount of information available for accurately estimating indoor pollution costs and the broad range of effects and resultant costs, there is considerable uncertainty in the cost estimates shown. It is important to note that costs for all indoor pollution impacts are not included, because many impacts cannot be reasonably quantified at this time. Costs for indoor PM-related illness and disease are likely to be very high, potentially in the billions of dollars.

Table ES-2. Estimated Annual Costs of Indoor Air Pollution in California.

Health End Point	**Health Valuation: Premature Death[1,2] ($ Billions/yr)**	**Medical Cost[1,2] ($ Billions/yr)**	**Lost Productivity Cost[1,2] ($ Billions/yr)**	**Total Cost [1] ($ Billions/yr)**
CO: poisoning	0.15	< 0.01	NA	0.15
VOCs: cancer	0.73	0.011	NA	0.74
ETS: lung cancer[3]	2.4	0.025	NA	2.4
ETS: heart disease	23	0.055	NA	23
ETS: respiratory disease[3,4]	NA	0.076	NA	0.076
ETS: low birth weight	NA	0.19	NA	0.19
Mold and moisture: asthma and allergies	0.031	0.19	NA	0.22
Sick building syndrome	NA	NA	8.5	8.5
TOTAL[5]	**26**	**0.6**	**8.5**	**35**

1. Estimates are based on average or mid-point of incidence rates of mortality and morbidity from sources discussed in the main report. Values are rounded to two significant figures.
2. Original data were adjusted to year 2000 dollars and year 2000 population.
3. These estimates are probably overestimates because they are based on 1996 U.S. smoking prevalence, which does not account for major reductions in smoking prevalence among Californians and the virtual elimination of workplace smoking in California by 2000. OEHHA is currently developing new risk estimates.
4. Combined total of asthma induction and exacerbation, bronchitis, and pneumonia.
5. Totals are rounded to two significant figures. These totals are likely low because conservative cost estimates were used, and quantitative information is not readily available for many known impacts of indoor air pollution, such as for indoor PM and many indirect costs of health effects. The actual impact on the California economy may be several times this total amount.

The combined cost of both fatal and non-fatal impacts due to indoor air pollution in California homes, schools, and non-industrial workplaces is substantial: it is estimated at **$35 billion per year**, as shown in Table ES-2. The annual valuation of mortality attributable to indoor air pollution is estimated to total about $26 billion, with most stemming from ETS. OEHHA is currently updating the risk estimates for ETS, to account for more recent risk information in the scientific literature and the major reductions in exposure to ETS due to virtual elimination of smoking in workplaces and the reduced prevalence of smoking in California. Thus, the relative ETS contribution may change in future versions of this report as updated estimates are finalized (most likely showing a decreased ETS contribution due to decreased exposure). However, the actual total valuation of mortality is likely to be higher because these estimates do not include the impacts of other pollutants that may increase the risk of premature death, such as other carcinogens emitted from materials and products; radon, and PM from wood smoke and other indoor combustion sources. The quantifiable medical costs (direct and some indirect) due to indoor air pollution total more than $0.6 billion per year, with a large portion of the costs attributable to mold and other moisture-related allergens. These cost estimates for morbidity do not include the potential losses due to other impacts such as those from other indoor allergens, the long-term effects of CO poisoning, reduced student performance, lost earnings opportunity, unpaid caregivers, and human suffering. Finally, the cost of reduced worker productivity due to indoor air pollution (primarily sick building syndrome) that could be prevented is estimated to be about $8.5 billion per year.

V. EXISTING REGULATIONS, GUIDELINES AND PRACTICES

Despite the significant health effects caused by indoor sources of pollution, there are few government standards restricting emissions from common sources of indoor pollutants, and there is no comprehensive program to protect air quality within residences, schools, or public and private buildings. A variety of agencies and organizations have established standards and guidelines that can be applied to indoor environments to assist in the assessment and control of health hazards from air pollutants. Foremost among these are workplace standards; however, those standards are designed for 8-hour exposures of healthy adults, are not as protective as standards set for ambient air, and are not designed to be protective of the more sensitive subgroups of the population, such as children. Others, such as ambient air quality standards, emission control regulations to improve ambient air quality, and Assembly Bill 13 (1995), which prohibits cigarette smoking in workplaces, are applicable to indoor air quality only in a limited way. Although many of these programs have resulted in improvements in indoor air quality as a secondary benefit, they do not ensure adequate control of many significant indoor pollution sources.

- **Workplace Standards.** The California Occupational Safety and Health Program (Cal/OSHA) in the Department of Industrial Relations (DIR) has authority to develop, promulgate, and enforce air pollutant exposure limits, ventilation regulations, and other standards for the workplace that directly impact indoor air quality. The California Occupational Safety and Health Standards Board is the unit within the Cal/OSHA program with authority to adopt standards and regulations to protect workers. Some of the Cal/OSHA standards and regulations that impact indoor air quality are the following:

  - ✓ **Permissible Exposure Limits**. The Standards Board sets permissible exposure limits (PELs) and other limits for airborne contaminants. The PELs are 8-hour exposure limits generally protective of the health of most workers. However, they do not protect vulnerable members of the population such as infants, the elderly, or individuals with pre-existing heart or respiratory disease. Additionally, they are not intended to be protective for exposures greater than eight hours per day, five days a week.

- ✓ **Ventilation**. Cal/OSHA requires employers to maintain and operate ventilation systems to provide at least the quantity of outdoor air required by the State Building Code at the time the building permit was issued. Annual maintenance inspections and maintenance records also are required.

- ✓ **Mold, moisture**. Cal/OSHA requires that workplaces be maintained in a sanitary condition, and that employers correct all types of water intrusion or leakage, to reduce the potential for mold growth/

- **Ventilation requirements.** Minimum ventilation levels for the quantity of outdoor air in new non-residential buildings, such as offices and public buildings, have been established by the California Energy Commission for different types of buildings and different types of rooms (e.g., conference rooms vs. offices). The Commission also sets energy efficiency standards for residences, which has resulted in reduced infiltration of outdoor air, or "tightening" of new homes compared to older homes. This has implications for indoor air quality, and the Commission is funding research to assess the need for revisions to the standard to assure healthful IAQ in homes.

- **Anti-smoking law**. Cigarette smoking, a major source of indoor pollution, is prohibited in nearly all public buildings in California. A statewide, smoke-free workplace law passed in 1995 (AB 13) eliminated smoking in nearly all California indoor workplaces–including restaurants, bars and gaming clubs–and spurred a reduction in smoking by the California population. The ban has been very successful in reducing worker exposure to cigarette smoke. In 1999, 93% of California's indoor workers reported working in a smoke-free environment, compared to only 45% in 1990 (Gilpin *et al.*, 2001).

  The prohibition of workplace smoking, along with the DHS Tobacco Control Program, have both had far reaching benefits. In 1994, 63% of Californians with children did not allow smoking in the house; by 2001, 78% did not allow it (Gilpin *et al.*, 2001). Additionally, smoking rates among California adults declined from 26% to 17% between 1984 and 2001 (BRFSS, 2001), leading to a reduced likelihood of ETS exposure.

- **State and national ambient air quality standards** (AAQS) and control programs**,** established by the ARB and U.S. EPA, respectively, are developed to protect the general public from the harmful effects of "traditional pollutants" in outdoor air, for specified averaging times (exposure times). California's AAQS are often more protective than the national AAQS. Currently, the state AAQS are under review to ensure that they are protective of sensitive populations, especially infants and children (ARB/OEHHA, 2000). In the absence of indoor air quality standards or guidelines, the AAQS serve as useful guideline levels for those pollutants indoors, because they are based on specified averaging times and incorporate a margin of safety. Both the state and federal AAQS are listed at http://www.arb.ca.gov/research/aaqs/aaqs.htm.

- **Consumer product standards**. The federal Consumer Product Safety Commission (CPSC) has jurisdiction over consumer products, except for pesticides, cosmetics, tobacco and cigarettes, food, drugs, automobiles, and a few others. CPSC has authority to ban a product, establish mandatory safety standards, recall products for repair or replacement, require warning labels, or develop voluntary standards in conjunction with manufacturers. However, CPSC is primarily focused on addressing safety issues, and most often uses voluntary processes and labeling requirements.

The ARB also regulates consumer products, for the purpose of reducing smog in California. An additional benefit is a reduction in the amount of certain types of VOCs that are released in homes and institutions. Reducing reactive VOC emissions from cleaning compounds, polishes, floor finishes, cosmetics, personal care products, disinfectants, aerosol paints, and automotive specialty products has likely reduced personal exposures to those VOCs.

- **Local woodburning ordinances.** Several communities in California have recently implemented woodburning ordinances or policies to reduce smoke emissions in their communities. For example, in the San Francisco Bay area, 24 cities have ordinances that prohibit conventional fireplaces in new construction. The mountain town of Truckee has a more aggressive policy that states that existing unapproved wood burning appliances must be removed from all properties by July 15, 2006. The San Joaquin Valley Air Pollution Control District issues daily advisories on restrictions for residential wood burning.

- **Guidelines and Public Education.**

  ✓ **OEHHA has developed acute and chronic reference exposure levels (RELs) as guidelines to prevent harm from toxic air pollution**, under the Air Toxics “Hot Spots” Information and Assessment Act of 1987 (HSC Section 44300 *et seq)*. Although established to identify healthful limits for outdoor air near industrial sources, RELs have been used for indoor pollutants as indicators of potential adverse health effects other than cancer. OEHHA has established chronic RELs for 71 air pollutants to define healthful levels for exposures that can last 12 years or more (OEHHA, 2003a), and acute RELs for 51 chemicals to define healthful levels for exposure of one hour (OEHHA, 2000a). OEHHA also has developed an additional REL for formaldehyde specifically for indoor application. The interim REL (IREL) for formaldehyde is 27 ppb, based on an 8-hour exposure period. This IREL identifies the level below which effects such as eye, nose, and throat irritation would not be expected to occur during typical daytime (8-hour) occupancy of buildings.

  ✓ **ARB Indoor Air Quality Guidelines** have been developed to advise the public regarding the health effects and indoor sources of key indoor pollutants, and what the public can do to reduce their exposures. Some AAQS are used as recommended maximum exposure levels in ARB’s Indoor Air Quality Combustion Pollutants Guideline. ARB’s guidelines for formaldehyde and chlorinated solvents recommend achieving as low a level of those pollutants as possible indoors, because they are carcinogenic, and there are no known levels that are absolutely safe.

  ✓ **DHS and other agencies** have developed various guidelines that can be applied to improve indoor environments. DHS published guidelines for reducing VOCs in new office buildings in 1996, played a key role in the development of Section 01350 emissions limits for materials used in state buildings, and has been directed to develop guidelines to prevent and remedy mold problems in buildings. The California Energy Commission (CEC) spearheaded the formation of the Collaborative for High Performance Schools (CHPS), which has developed *Best Practices Manuals* that include guidance for selecting building materials with reduced indoor pollutant emissions. The U.S. EPA has developed its *IAQ Tools for Schools Program* to provide guidance for assuring healthful indoor air quality in schools. All of these and ARB's indoor guidelines are available at no charge on the Internet.

✓ **Industry and professional guidelines** include the American Society of Heating, Refrigerating, and Air-conditioning Engineers' (ASHRAE) ventilation requirements for assuring adequate indoor air quality, the Carpet and Rug Institute's (CRI) Green Label Program, the Composite Wood Manufacturers' voluntary formaldehyde limits, and a number of others. They vary in their degree of IAQ protection, but are widely used and generally have helped reduce indoor pollutants over the years.

VI. METHODS TO PREVENT AND REDUCE INDOOR AIR POLLUTION

There are a number of methods that can be used to prevent or reduce indoor air pollution. The most effective approach is to remove or reduce indoor emissions by using building materials, consumer products, and appliances that emit little or no air pollution. Ventilation (including proper exhaust ducting) and public education also are important components of a strong indoor air quality improvement program. Air cleaning devices (air filters and air cleaners) can be helpful in certain situations; however, their effectiveness is often limited, and some air cleaners actually release ozone into the indoor environment, adding to the indoor pollutant burden.

- **Reduction at the source** is most effectively achieved through use of low- or zero-emitting appliances, products or materials, or reformulation of chemical products. Low emission product designs or reformulations can usually be accomplished by the manufacturer, with minimal impact on the consumer, often with only minor increased costs. For example, reactive constituents (i.e. terpenes, such as limonene or pinene, which provide the lemon or pine scent to products) contribute to the formation of toxic pollutants indoors. Terpenes could be removed from many products, thereby reducing related health risks. Similarly, indoor formaldehyde levels can be greatly reduced by using low- or no-emitting composite wood building materials instead of materials made with urea-formaldehyde resins.

> **Minimizing indoor emissions is generally more effective than removing them after emission has occurred.**
>
> *T.J. Kelly, Battelle, Indoor Air Quality Symposium: Risk Reduction in the 21st Century, Sacramento, May, 2000*

- **Ventilation** is a standard engineering approach to assuring good indoor air quality and comfort. Natural ventilation, through open windows and doors, is the primary ventilation route for residences, while mechanical ventilation, using HVAC systems, is most common in commercial buildings. Adequate and effective ventilation, and ducting of exhaust from combustion appliances, are necessary for acceptable indoor air quality, even when known air contaminants are minimized. Ventilation not only removes and dilutes indoor contaminants, it also removes moisture from the air which helps to prevent mold growth, and removes body effluents such as carbon dioxide that lead to a stuffy environment. However, ventilation is not a complete solution to indoor pollution. Ventilation consumes energy, and some pollutants, such as formaldehyde emitted from building materials, require years to off-gas and are not completely removed by ventilation. Finally, the benefits of ventilation are reduced when outdoor air pollution is present, because indoor pollutants will just be replaced with outdoor pollutants.

- **Public education** is a key step for reducing Californians' exposures to many indoor air pollutants. People's choices and activities have a major impact on their exposures to air pollution. The use of various consumer products, cigarette smoking, cooking, and other activities can result in significant indoor releases of pollutants. However, public education is not a complete solution. Some groups of the population cannot respond appropriately to take needed action. For example, children cannot read or understand all written information that is provided, elderly people living in group settings cannot control the products used in their facility, and low-income families may not be able to afford safer alternatives, even when they are aware of them.

- **Air cleaning devices** can also help improve indoor air quality; however, their effectiveness is often very limited. Air cleaning devices include both central air filters and portable air cleaning appliances. Air filters are a normal component of mechanical HVAC systems in public and commercial buildings; high efficiency particulate arrestor (HEPA) filters are most effective at removing particles from outdoor air as it is brought indoors. Air cleaning appliances are usually portable units used indoors to remove particles from the indoor air, although a few remove gases, and some do both. Mechanical air cleaners typically draw air through a filter while electronic air cleaners remove pollutants with the use of an electric charge. Electrostatic precipitators (ESPs) and ionizers are the two major types of electronic air cleaners on the market.

  The proper size and type of air cleaner may help control airborne particles for people with special sensitivities, such as those with asthma or allergies, who use them in confined spaces such as in their bedrooms. However, the limited scientific evidence available has not documented any health benefits from air cleaners. Air cleaning appliances are generally not effective at removing gaseous pollutants, and typically are not designed to do so. Additionally, ESPs and ionizers can produce ozone as a by-product; thus proper use and maintenance is critical to prevent harmful levels from developing when using these devices.

  Air cleaners that intentionally generate ozone should not be used indoors (DHS, 1998; ALA, 1997). Independent studies by the U.S. EPA, the Consumers Union, and others have shown that ozone-generating air cleaners do not effectively destroy microbes, remove odor sources, or reduce indoor pollutants enough to provide any health benefits. These devices can emit substantial amounts of ozone, but they are currently unregulated.

Air Cleaners

"People should avoid using indoor air cleaning devices that produce ozone…These devices can quickly produce enough ozone in a confined space to exceed the California Stage 2 and 3 smog alert levels as well as worker health and safety standards."

Jim Stratton, M.D., M.P.H., State Health Officer. Department of Health Services, Press Release 27-97, Sacramento, April 1997.

- **Finally, proper operation and maintenance of buildings** is critical to achieving and maintaining healthful air quality in buildings. Ventilation systems should be maintained as intended and filters replaced routinely to prevent soiling and the growth of mold and bacteria in the ventilation system and in the occupied space. Roof leaks that are not repaired promptly can lead to moisture intrusion and mold growth. Such factors not only lead to poor indoor air quality, but can also prove more costly in the long term due to increased costs to remedy the larger problems that result.

VII. PRIORITIZATION OF INDOOR SOURCES BASED ON EXPOSURE AND ADVERSE IMPACTS

Table ES-3 suggests a prioritization scheme for implementation of mitigation measures, by source categories, based generally on estimated exposure and risk, with the highest priority categories listed first. The primary criteria used in prioritizing the source categories included the extent of the population's exposure to the sources and their emissions, and the relative reduction in health impacts that could be achieved with action.

Table ES-3 also suggests potential approaches for mitigating the pollutants and sources listed. Emission reductions should be implemented at the manufacturing, distribution, or construction stage whenever feasible. Alternatives or mitigation options are currently available for most of the sources listed. The highest priority is replacing high formaldehyde-emitting composite wood products with lower-emitting products. Products made with urea-formaldehyde resin should be replaced with materials made with phenol-formaldehyde resin, laminated products, or other alternative materials with much lower formaldehyde emissions. Additionally, formaldehyde emissions from home furnishings, permanent pressed draperies and clothing, and other sources also should be reduced.

Exposure to environmental tobacco smoke has been greatly reduced in California. However, children's exposures remain a concern, because they can be highly exposed when smoking occurs in their home or in vehicles driven by family or friends who smoke. Actions to reduce children's exposure–such as an increased focus of public education on smoking parents–remain a high priority.

Reducing exposure to emissions from combustion appliances is also a high priority. Gas and propane appliances could be improved to emit lower levels of pollutants, and paired with active exhaust ventilation features or safety devices to assure exposure reduction. Such measures would help reduce both CO impacts and respiratory effects from nitrogen oxides. Statewide measures to reduce emissions from woodstoves and fireplaces are also highly desirable; these could have a major impact on improving both community-wide indoor and outdoor air quality in many areas of the state. As discussed above, a number of local government entities have recently approved regulations restricting the use of woodstoves and fireplaces. Woodsmoke especially impacts those with asthma and other respiratory disease.

Indoor air cleaning devices that emit ozone are another source of pollutants that should be restricted. By their nature, air cleaners should clean the indoor air, not pollute it. Air cleaners that purposely emit ozone should be prohibited in occupied spaces, because they are ineffective at safe levels and produce potentially harmful levels of indoor ozone, and effective alternatives are available. Additionally, requirements for a pollutant removal efficiency rating would assist the consumer in making decisions when purchasing an air cleaner.

Table ES-3. Prioritization of Pollutant Sources for Mitigation[1]

Sources of Pollutant	Examples of Toxic Air Pollutants[2] Emitted	Potential Approach to Mitigation[3]
Building Materials & Furnishings (particle board, plywood, paneling, flooring, caulk, adhesives, carpet, furniture)	Formaldehyde, acetaldehyde, benzene derivatives, acrylates, naphthalene, phenol, other VOCs	Emission limitations, product use restrictions, market incentives
Environmental Tobacco Smoke	Particles, polycyclic aromatic hydrocarbons, benzene, carbon monoxide, VOCs	Focused parent education; reduce smoking in homes and vehicles
Combustion Appliances (gas & propane stoves, ovens, furnaces, heaters; woodstoves and fireplaces)	Carbon monoxide, nitrogen oxides, particles, soot, polycyclic aromatic hydrocarbons	Emission limitations, active exhaust ventilation, safety devices, product use restrictions, product re-design, improved venting
Air Cleaners	Ozone, particles	Emission limitations, efficiency ratings
Consumer Products (e.g. household cleansers, furniture- and floor-care products, air fresheners, stain removers, detergents)	Methylene chloride, para-dichlorobenzene, perchloroethylene, terpenes, toluene, benzene, naphthalene	Emission limitations, chemical reformulations, and product use restrictions to reduce TACs and nonreactive VOCs with health impacts; labeling program
Architectural Coatings (e.g. paints, sealants, lacquers, varnishes)	Formaldehyde, acetaldehyde, ethylene glycol, metals, others	Emission limitations, chemical reformulations, use restrictions to reduce TACs & nonreactive VOCs with health impacts;
Personal Care Products (e.g. products used for hair and skin care)	Formaldehyde, acetaldehyde, toluene, metals, others	Emission limitations, chemical reformulations to reduce TACs and nonreactive VOCs
Household & Office Equipment and Appliances (computers, photocopy machines, vacuum cleaners)	Particles, styrene, VOCs, phthalates, ozone, PBDE	Emission limitations, local exhaust requirements

1. Source categories are presented in general order of prioritization. However, individual sources in a lower priority category may supersede some sources in “higher” priority categories.
2. Toxic Air Pollutants: pollutants identified as Toxic Air Contaminants (TACs) by the California Air Resources Board, and/or identified as Proposition 65 chemicals; or, criteria (traditional) air pollutants.
3. Public education, economic incentives, and non-regulatory approaches should also be used where appropriate. The actual approach taken would be determined after extensive discussions with the relevant industries, in consideration of costs, feasibility, and effectiveness.

Consumer products, architectural coatings, and personal care products have been regulated to reduce emissions of reactive VOCs in order to reduce smog formation. Further restrictions to assure reduction of toxic air contaminants and nonreactive VOCs with potential health implications appear warranted. A few such measures have already been taken: for example, in the 1990s, trichloroethylene was eliminated from a brand of typewriter correction fluid, thereby reducing indoor exposures to this chemical. Also, the ARB previously required that chlorinated solvents be removed from aerosol adhesives by January 1, 2002. Reformulation of other products, such as cleaning agents to remove terpenes, could go far to reduce irritant and carcinogenic effects. Alternative products or formulations must be recommended with care, however: substitutes should not result in increased emissions of, or exposures to, other toxic pollutants. Efforts focused on these source categories are a medium priority.

Finally, household appliances and equipment such as computers and vacuum cleaners can emit VOCs that are carcinogenic, and fine particles from exhaust. In most cases, these pollutants are emitted directly into the living area. Restrictions on emissions from such products are warranted, again with a medium priority. As further research is conducted on these sources, some products may become a high priority for emission reductions.

VIII. OPTIONS TO MITIGATE INDOOR AIR POLLUTION

This report has shown that there are many sources of indoor air pollution that produce substantial adverse health effects, result in lost productivity, and require considerable expenditures for health care. Despite these facts, there is no systematic program to improve indoor air quality, there are relatively few regulations or standards to address individual indoor air quality problems, and few resources focused on effectively addressing problems and promoting improvements. Current efforts to address indoor pollution are not commensurate with the scope of the risk to health it poses to Californians.

In California and under federal law, ambient (mainly outdoor) air quality is protected through a comprehensive system that requires that air quality standards be set and attained for selected pollutants. Pollutants identified as toxic air contaminants must be reduced to the maximum extent feasible. The approach used to reduce toxic air contaminants in ambient air, in which source emissions are reduced without setting enforceable air quality levels, seems most applicable to indoor air. While regulatory action to reduce emissions and exposures would assure reduction of exposure and risk from key sources and be a major component of a new effort to address indoor air, other approaches including public education, product testing and labeling, and setting of maximum exposure guideline levels, should also be part of the mix. The following elements of an indoor air pollution reduction program are recommended for consideration:

1. Create a management system for indoor air quality that establishes and assigns authority and responsibility for assessing indoor health problems, identifies the actions needed to reduce the most significant problems, and sets emissions standards or other requirements.

2. Authorize the appropriate state agencies to establish emission limits for building materials, furnishings, combustion appliances, air cleaners, and other indoor pollutant sources that pose excessive risks due to their indoor emissions.

3. Require emissions testing by manufacturers of building materials, furnishings, combustion appliances, consumer products, and other significant source categories, and labeling in

language consumers can understand. A prototype emissions testing program has already been developed for state sustainable building projects; however, there is currently no requirement for state agencies or others to use these guideline emission specifications.

4. Make children's health in schools, homes, and daycare institutions the top priority. Implement the recommendations for schools in the section below.

5. Develop indoor exposure standards or guidelines for homes, schools, offices, and institutional living quarters. Establish a state policy of using indoor air quality "Best Practices" in the design, construction, operation and maintenance of public, commercial, school, and institutional buildings. Require IAQ to be fully addressed in government procurement and construction activities, and require full commissioning for all new public, commercial, and institutional residential buildings, to assure that they are constructed and operate as intended, and that they provide acceptable indoor air quality.

6. Increase efforts to reduce children's exposure to environmental tobacco smoke. Substantial education and outreach efforts to smoking parents and caretakers are needed to inform them of the health dangers of second-hand smoke, and the actions they should be taking to protect children under their care from these dangers.

7. Amend building codes to address indoor air quality. For example, unvented cook stoves, ovens, and combustion appliances should not be allowed in residences.

8. Fund an outreach and education program, especially focused on health professionals, teachers, school facility managers, and related professionals who must be able to identify and remedy indoor air quality problems.

9. Conduct more research on indoor air quality. Many pollutants have not been studied, and synergistic and cumulative health effects are not understood.

10. Fund an Innovative Clean Air Technology program (ICAT) for indoor air quality to foster the development and commercialization of legitimate, cost-effective technologies that can improve IAQ. For example, improved ventilation technologies, improved air monitors and assessment tools, and effective low-noise air cleaners are needed.

Mitigating Indoor Pollution in Schools: An Urgent Need

The Air Resources Board and Department of Health Services recently completed a statewide study of kindergarten through 12th grade public schools entitled "Environmental Health Conditions in California's Portable Classrooms" (ARB/DHS, 2003). Results showed there are a number of serious, widespread environmental health problems in California schools that need to be addressed. These problems were found in both portable (relocatable) and traditional (site-built) classrooms. Government standards and guidelines that are designed to protect children in classrooms and other buildings are essentially lacking; thus, results were compared to the most relevant environmental health guidelines and standards available, primarily from professional societies and government agencies.

Problems in Schools

The primary problems found include:

- Inadequate ventilation with outdoor air during 40 percent of class hours, and seriously deficient ventilation 10 percent of the time. This is often due to teachers turning off HVAC systems because of excessive noise.

- Formaldehyde air concentrations exceeded guideline levels for preventing acute eye, nose, and throat irritation in about 4 percent of the classrooms; nearly all classrooms exceeded guidelines for preventing long-term health effects, including cancer.

- Obvious mold in about 3 percent of classrooms, and water stains and other potential mold indicators in about one-third of classrooms, due to inadequate maintenance.

- Noise levels in all classrooms exceeded 35 decibels, a voluntary standard for classrooms; one-half of the classrooms also exceeded 55 decibels, the level used for outdoor nuisance regulations. Excess noise was primarily attributable to noisy ventilation systems.

Recommendations to Address the Problems Identified

Recommendations to address the problems identified in the study were developed in consultation with state agencies, industries, school officials, and other interested stakeholders. Actions are needed at all levels. A total of 16 recommendations are discussed in the November, 2003 Report to the Legislature. These are presented in two groups in the report: Group 1 includes high priority, high benefit actions that can be achieved at relatively low cost and should be accomplished in the near term, while Group 2 recommendations will require a longer timeframe and/or more substantial resources to accomplish. The recommendations fall into four general approaches needed to remedy and prevent the problems seen. These include:

- Direct and assist schools to comply with state regulations, especially Cal/OSHA's workplace regulations related to ventilation, moisture intrusion, and other aspects of building operation and maintenance. Schools should conduct a self-assessment and implement an indoor air quality management program, like that in U.S. EPA's *IAQ Tools for Schools Program.*

- Develop and promote "Best Practices" for design, construction, operation, and maintenance of school facilities. The CHPS manuals provide comprehensive guidance at no charge.

- Improve support (both funding and training) for school facilities and staff. Stable, long-term funding mechanisms are needed to assure adequate and timely operation and maintenance. Postponed maintenance often results in greater costs. Focused training programs for administrators, facility managers, and teachers are needed: those closest to the classroom are often not aware of current "best practices" for operation and maintenance of classrooms.

- Establish guidelines and standards for school environmental health that are protective of children. Noise, lighting, and chemical contaminant levels appropriate for school children need to be identified.

Some actions have already been taken to begin to address these problems; however, they constitute only a first step toward realizing actual improvements in school conditions. Only a small percentage of schools and districts have actively pursued the many tools that are readily available to them to improve the school environment. The CHPS' *Best Practices Manuals*, U.S. EPA's *IAQ Tools for Schools Kits*, and the LAUSD's "Safe School Inspection Guidebook" are all available on the Internet free of charge, yet the number of California schools utilizing these tools is small. A proactive effort to implement the recommendations of the report is needed.

The complete *Report to the Legislature on Environmental Health Conditions in California's Portable Classrooms* is available at http://www.arb.ca.gov/research/indoor/pcs/pcs.htm.

IX. SUMMARY

Indoor pollution causes substantial, avoidable illness and health impacts–ranging from irritant effects to asthma, cancer, and premature death–and costs Californians billions of dollars each year. Because there are numerous sources of pollutants in indoor environments, and because people spend most of their time indoors, exposure and the associated risk is substantial. Many agencies, professional groups, and organizations have taken actions to reduce indoor pollution, but these have been piecemeal and are not sufficiently effective in addressing the problem.

There are many actions that could be taken to significantly reduce indoor emissions and exposure. If experience in controlling sources of outdoor pollution is repeated relative to indoor sources, many of these measures will be low cost and will provide substantial health benefits. A focused risk reduction program is needed to effectively assure acceptable indoor air quality in California homes, schools, and public buildings. A program that stresses direct emission reductions is recommended, but education, ventilation, labeling, and advisory standards also should play a role. Building materials, furnishings, woodstoves and fireplaces, and indoor air cleaning devices are high priority sources. High priority pollutants include formaldehyde, environmental tobacco smoke, and toxic VOCs. Biological contaminants such as mold and other irritation-causing contaminants should also receive priority. Special priority should be paid to measures that reduce children's exposures.

It should be noted that indoor air controls cannot be substituted for the state and national ambient air quality programs. As discussed above, indoor and outdoor pollution operate in tandem, increasing the health risk to all Californians. That means that any new initiatives to mitigate indoor air pollution must be accomplished alongside California's decades-long efforts to improve our outdoor environment.